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Impact of weather on the spring crops yield in Croatia with emphasis on climatic change and the 2014 growing season

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SUMMARY

Main field crops in Croatia are maize, soybean, sunflower and sugar beet. By these crops are covered (status 2014) close to 50% (385 234 ha) of utilized arable land. Global warming, have often adverse influence on field crop yields. Aim of this study was testing precipitation and temperature regimes on spring crops yield in Croatia in 15-year period (1999–2013) and elaboration of the 2014 growing season with aspect of climatic change.

Four growing seasons (2000, 2003, 2007 and 2012) were less favorable for maize because annual yield was bellow 5 t ha^{-1} (average 4.38 t ha^{-1}), while in four more favorable years (2005, 2008, 2009 and 2010) annual yield was above 6.8 t ha^{-1} (average 7.32 t ha^{-1}). Average precipitation and temperature for the April-September period in Osijek were 226 mm and 496 mm, 19.6 °C and 18.6 °C, for less and more favorable years, respectively. Yields of soybeans and sugar beet have mainly similar trend as maize yields in function of weather conditions, while sunflower is more susceptible to extremely moist growing seasons (for example, 2001 and 2005: 650 mm and 697 mm precipitation and very low yields in level 1.7 and 1.6 t ha^{-1}, respectively). On the other side, under drought conditions of 2003, 2007 and 2012, yields of sunflower were above average in range from 2.5 to 2.7 t ha^{-1}), while at same period yields of maize, soybean and sugar beet were drastically reduced.

Average precipitation in the April-September period of 2014 for eight selected sites of Croatia was 756 mm or for 68% higher in comparison with the long-term average 1961–1990 with variation among the sites from 520 mm in Osijek to 910 mm in Varazdin. On the other side, average air-temperature in 2014 was 17.8 °C or for 0.7 °C higher with variations among the sites from 17.2 °C in Daruvar and Varazdin to 18.2 °C in Osijek and 18.3 °C in Gradiste. Under these favorable weather conditions, annual yields of maize (8.1 t ha^{-1}), soybeans (2.8 t ha^{-1}) , sunflower (2.9 t ha^{-1}) and sugar beet 63.6 t ha^{-1}) were considerable higher than usual.

Keywords: *maize, sunflower, soybeans, sugar beet, climatic change, precipitation, temperature, Croatia*

INTRODUCTION

Main field crops in Croatia are maize, soybean, sunflower and sugar beet. By these crops were covered (status 2014) 252 567 ha (maize for grain), 28 794 ha (silage maize), 47 104 ha (soybeans), 34 869 ha (sunflower) and 21 900 ha (sugar beet) or 47.5% (385 234 ha) of utilized arable land (CBS, 2015).

Global warming and more frequency of the extremely weather conditions, mainly long drought periods and floods, is associated with climatic change. With that regards, recent status of precipitation and temperature regimes, have often adverse influence on field crop yields as well the higher amplitude their variations among years. For this reason, in many countries there is a tendency towards cereal grain yield stagnation and increased yield variability (Tim, 2000; Chi-Chung et al., 2004; Parrx et al., 2004; Vucetic, 2006, 2011; Lobel and Field, 2007; Li et al., 2011; Oseni and Masarirambi, 2011; Kovacevic et al., 2012, 2014; Liovic et al., 2012; Komljenovic et al., 2014). Some studies have indicated that 1 °C increase in global temperature will lead to reduced productivity in some cultivated plants, such as 17% in maize and soybean (Allen et al., 2003; Thomson et al., 2005). In the recent period, very high yield reduction of maize due to drought and high air-temperatures were found for the continental climate in the Pannonia zone, which includes Hungary, Croatia, Serbia, Bulgaria and Romania (Kovacevic et al., 2012, 2013).

Aim of this study was testing precipitation and temperature regimes on spring crops yield in Croatia in recent 15-year period (1999–2013) and elaboration of the 2014 growing season with aspect of climatic change.

MATERIAL AND METHODS

Description of the area

According to geographical characteristics, there are three regions in Croatia: the Mediterranean or the Adriatic region, the Mountainous region and the Pannonia region. The Pannonian region covers about 50% of Croatian territory and majority arable land and the harvested area of main field crops of the country is situated in this part of Croatia. More details about geographical position, relief, soil, climate and water resources, as well as phytogeographical characteristics, were shown in the correspondingly monography (Magas, 2013), while Kovacevic and Basic (1997) reported data with emphasis on the agroecological aspect.

The meteorological stations of eight sites situated in Pannonia region of Croatia (*Figure 1*) were selected for characterization of weather conditions with aspect of their degree of favorability for the spring crops growth in the 2014 growing season. This region is mainly lowland area and selected sites are elevated between 81 to 163 m above sea level (*Figure 1*).

Collection of data

Publications of Croatian Bureau of Statistics were used as the sources of the utilized agricultural and arable land areas, the spring crops (maize, soybeans, sunflower and sugar beet) harvested areas and yields (CBS, 2009, 2014, 2015), while publications of Meteorological and Hydrological Service Zagreb were

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perused for the meteorological data (monthly values of precipitation and average air-temperatures (MHS, 1999–2013, 2014).

RESULTS AND DISCUSSION

By utilized agricultural area in Croatia were covered 1 270 044 ha (average 2004–2013) and 1 508 885 ha (status 2014) and utilized arable land participated with 68.6% and 53.7% of utilized agricultural area, respectively. Main spring crops on arable land in Croatia are maize for grain, soybean, sunflower and sugar beet (averages in 2004–2013 period: 301 046 ha, 49 121 ha, 33 081 ha and 25 644 ha, respectively). In general, considerable yield variations of the mentioned crops among years were found. With that regards, the 2014 growing season characterized by yields above 10-year averages (*Table 1*). As soil properties, crop management practices and used cultivars in this short period were similar, yield differences among years could be attributed mainly to specify of weather characteristics in individual growing season.

Figure 1: **Position of selected meteorological stations (MS), their geographical coordinates and elevation above sea level**

MS	Coordinates and elevation
Osijek (OS)	45°33'44"N 18°42'00"E; 102 m
Gradiste (GR)	45°04'20"N 18°41'40"E; 81 m
Slav. Brod (SB)	45°09'36"N 18°00'36"E; 90 m
Daruvar (DA)	45°35'34"N 17°13'25"E; 163 m
Bjelovar (BJ)	45°54'36"N 16°50'24"E; 111 m
Sisak (SI)	45°28'48"N 16°21'36"E; 102 m
Zagreb (ZG)	45°48'43"N 15°58'52"E; 125 m
Varazdin (VZ)	46°18'15"N 16°20'16"E; 154 m

From OS to VZ: air-distance approximately 200 km

Table 1.

The harvested areas and yields of main spring field crops in Croatia

The utilized area (ha)		The harvested area (ha)					Yield ($t\ ha^{-1}$)				
Agric. area	Arable land	Maize Grain	Maize Silage	Soybean	Sunflower	Sugar-beet	Maize Grain	Maize Silage	Soybean	Sunflower	Sugar-beet
Republic of Croatia – 10-year averages (2004–2013)											
1 270 044	871 321	301 046	26 547	49 121	33 081	25 644	6.35	31.6	2.45	2.60	49.6
		Annual yield variation in 2004–2013 period: Minimum					4.40	25.8	1.80	1.60	39.1
						Maximum	8.00	37.5	3.00	3.20	57.7
Republic of Croatia – the 2014 growing season											
1 508 885	811 067	252 567	28 794	47 104	34 869	21 900	8.10	35.3	2.80	2.90	63.60

Source: CBS (2009, 2014, 2015)

Variation of maize yields in Croatia during 15-year period 1999–2013 could be used as typical example of impact precipitation and temperature regimes on maize yields. Annual yield variation in this period was from 4.1 $t\ ha^{-1}$ in 2000 to 8.0 $t\ ha^{-1}$ in 2008. Four growing seasons were less favorable for maize (2000, 2003, 2007 and 2012) because annual yield was below 5 $t\ ha^{-1}$ (average 4.38 $t\ ha^{-1}$), while in four more favorable years (2005, 2008, 2009 and 2010) annual yield was above 6.8 $t\ ha^{-1}$ (average 7.32 $t\ ha^{-1}$). Average precipitation and temperature for the April-September period in Osijek were 226 mm and 496 mm, 19.6 °C and 18.6 °C, for less and more favorable years, respectively (*Table 2*).

Low yields of maize in unfavorable years were in close connection with drought in June and August (total 15 mm precipitation) and high air-temperature (23.7 °C) in August of 2000, high temperatures in June (24.3 °C) and August (23.6 °C) accompanied with moderate precipitation in 2003, drought and high temperature in June and July of 2007 (58 mm precipitation and temperature 23.1 °C) in 2007, while extremely drought and high temperature in August (4 mm and 24.8 °C) were responsible for low yield of maize in 2012 (*Table 2*). Specifies of unfavorable the 2012 growing season (Meteorological Station Osijek) were the highest average air-temperature in level 20.0 °C for April-September period (*Table 3*) and absolute maximum in August 40.3 °C (Kovacevic et al., 2013). The highest annual yield of maize in Croatia for 1999–2013 periods were recorded in 2008. This growing season was characterized by adequate (404 mm) and good distributed monthly precipitation, as well as the lower temperature (average 18.1 °C) without considerable oscillations (21.5 °C in June, 21.8 °C in July and 21.8 °C in August).

Kovacevic et al. (1994) reported survey of maize yield and precipitation regime for 1960–1990 period in Slavonia and Barannya which approximately covers the eastern Croatia region. In this study was found similar impact of weather conditions on maize yield as in our study. In this period, the average harvested area of maize in Croatia 509 068 ha and it was relative stabile among the years, while yields had the increasing trend

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as follows: 2.90 t ha^{-1}, 3.85 t ha^{-1} and 4.68 t ha^{-1}, for decade periods 1960-ies, 1970-ies and 1980-ies, respectively.

Yields of soybeans and sugar beet have mainly similar trend as maize yields in function of weather conditions impacts, while sunflower is more susceptible to extremely moist growing seasons (for example, 2001 and 2005: 650 mm and 697 mm precipitation and very low yields in level 1.7 and 1.6 t ha^{-1}, respectively) compared to remaining three analyzed spring crops. On the other side, under drought conditions of 2003, 2007 and 2012, yields of sunflower were in range from 2.5 to 2.7 t ha^{-1}), while yields of maize, soybean and sugar beet were drastically reduced (*Table 2*).

Average precipitation in the April-September period of 2014 for eight selected sites of Croatia was 756 mm or for 68% higher in comparison with the long-term average (LTA) 1961–1990 with variation among the sites from 520 mm in the eastern situated Osijek to 910 mm in western situated Varazdin. On the other side, average air-temperature in 2014 was 17.8 °C or for 0.7 °C higher with variations among the sites from 17.2 °C in Daruvar and Varazdin to 18.2 °C in Osijek and 18.3 °C in Gradiste (*Table 3*). In general, climate trend in the Pannonia region is characterized by increase of annual precipitation and decrease of temperature in direction from east toward west (Rastija et al., 2012; Magas, 2013; Kovacevic and Rastija, 2014). Our data are in accordance with these observations. Also, we confirmed of climate change by global warming (Lobel and Field, 2007; Vucetic, 2011).

The 2014 growing was very favorable for the majority spring crops because of adequate and good monthly distributed precipitation and avoidance of extremely high air-temperatures (*Table 3*).

Table 2.

Yields of main spring crops in Croatia and weather conditions in Osijek

	Year														
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
	Yields of main spring crops in Croatia (t ha^{-1})														
Maize	5.6	4.1	5.7	6.4	4.2	6.3	6.9	6.5	4.9	8.0	7.4	7.0	5.7	4.3	6.5
Soybean	2.5	1.4	2.2	2.7	1.7	2.7	2.5	2.8	1.9	3.0	2.6	2.7	2.5	1.8	2.4
Sunflower	2.1	2.1	1.7	2.3	2.5	2.4	1.6	2.3	2.6	3.1	3.0	2.3	2.8	2.7	3.2
Sugarbeet	40.0	23.0	40.6	47.1	24.8	47.6	45.5	48.9	46.1	57.7	52.8	52.4	53.8	39.1	51.9
	Precipitation in Osijek (mm)														
April–September	505	155	650	461	227	471	697	417	229	404	206	677	246	293	425
June	150	10	239	37	44	77	112	91	33	76	63	234	50	68	63
July	96	63	77	59	60	44	171	15	27	79	14	32	74	48	37
August	74	5	7	84	42	107	238	134	45	46	61	111	5	4	33
	Mean air-temperature in Osijek (°C)														
April–September	18.7	19.7	17.8	18.3	19.6	17.3	17.7	18.3	19.1	18.6	19.6	18.3	19.4	20.0	18.6
June	20.3	22.5	18.1	21.1	24.3	19.2	19.5	20.1	22.3	21.5	19.2	20.4	20.8	22.5	20.0
July	21.9	21.7	21.6	22.3	22.1	21.5	21.5	23.5	23.8	21.8	23.2	23.2	22.2	24.8	22.9
August	21.3	23.7	22.7	20.9	23.6	21.0	19.3	19.3	22.2	21.8	22.9	21.7	23.1	24.1	22.9

Source: CBS (2005, 2009, 2014), MHS (1999–2013)

Table 3.

Weather conditions in eight selected sites of Pannonian region in Croatia (MHS, 2014)

Month	Precipitation and mean air-temperatures in eight sites* of Croatia																	
	The meteorological station									The meteorological station								
	OS	GR	SB	DA	BJ	SI	ZG	VZ	x	OS	GR	SB	DA	BJ	SI	ZG	VZ	x
	The 2014 growing season									Average 1961–1990								
	Precipitation (mm)																	
April	81	88	119	123	106	124	70	105	102	54	53	58	77	54	73	64	70	63
May	159	165	134	191	168	193	145	109	158	59	66	73	86	59	82	79	84	74
June	91	46	78	54	80	74	147	118	86	88	81	86	99	88	91	100	98	91
July	66	83	76	132	144	153	158	134	118	65	72	83	86	65	77	83	92	78
August	54	94	132	125	127	169	115	153	121	59	66	73	91	58	85	95	98	78
September	69	96	113	197	204	214	179	291	170	45	56	62	65	65	76	79	81	66
Total	520	572	652	822	829	927	814	910	756	370	394	435	504	389	484	500	523	450
	Mean air-temperature (°C)																	
April	13.2	13.3	12.8	12.3	13.0	13.1	13.3	12.7	13.0	11.3	11.5	10.9	11.0	11.3	11.1	10.6	10.3	11.0
May	16.1	16.2	15.7	14.9	15.4	15.8	15.7	15.0	15.6	16.5	16.7	15.9	15.7	16.5	15.8	15.3	15.1	15.9
June	20.4	20.7	20.0	19.6	20.1	20.3	20.2	19.3	20.1	19.5	19.6	19.0	18.9	19.5	19.1	18.5	18.3	19.1
July	21.8	22.1	21.7	21.0	21.6	21.7	21.8	21.1	21.6	21.1	21.2	20.7	20.6	21.1	20.8	20.1	19.8	20.7
August	20.8	20.9	20.6	19.7	20.2	20.2	20.2	19.2	20.2	20.3	20.7	19.8	19.7	20.3	19.8	19.3	18.9	19.9
September	17.0	16.8	16.5	15.7	16.2	16.2	16.2	15.8	16.3	16.6	16.6	16.1	16.1	15.8	16.0	15.8	15.4	16.1
Mean	18.2	18.3	17.9	17.2	17.8	17.9	17.9	17.2	17.8	17.6	17.7	17.1	17.0	17.4	17.1	16.6	16.3	17.1

Source: MHS (2014), Note: * Osijek (OS), Gradiste (GR), Slavonski Brod (SB), Daruvar (DA), Bjelovar (BJ), Sisak (SI), Zagreb-Maksimir (ZG), Varazdin (VZ)

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In general, low yields of maize are in close connection with drought accompanied with high temperatures, particularly in two summer months July and August (Kovacevic et al., 2012; Stojic et al., 2012; Kovacevic et al., 2013; Videnovic et al., 2013; Majdancic et al., 2016). Weather conditions have similar role as in maize for their impact on yields of the other spring crops (Liovic et al., 2012; Vrataric and Sudaric, 2008; Kovacevic and Kaucic, 2014). Also, yields of winter crops are under considerable impacts of weather conditions, for example wheat (Marijanovic et al., 2010; Pepó and Kovacevic, 2011; Sostaric et al., 2014; Majdancic et al., 2016) and other winter crops (Iljkic et al., 2014).

Vucetic (2011) studied the impact of present climate on maize yield using DSSAT 4.0 with meteorological data from the Zagreb–Maksimir station covering the period 1949–2004.The location is representative of the continental climate in central Croatia. The linear trends of model outputs and the non-parametric Mann–Kendall test indicate that the beginning of silking has advanced significantly by 1.4 days/decade since the mid-1990s and maturity by 4.5 days/decade. It also shows a decrease in biomass by 122 kg ha^{-1} and in maize yield by 216 kg ha^{-1} in 10 years.

Kovacevic et al. (2012) analyzed the data of the two-decade period between 1990–2012 of precipitation and temperature, with aspect of climatic in Serbia with emphasis on the Belgrade region. Annual air temperatures in the investigated period increased not only at the annual level, but also in the vegetative period of winter wheat and particularly maize. The temperature increase is particularly dangerous in the vegetative period of maize during June, July and August by almost 2 ^{o}C. Precipitations at a monthly level of the vegetative period or a total per year do not provide such a picture. Besides the lack in July, precipitations are somewhat higher than the reference 30-year period 1971–2000.

Irrigation in critical stages under water deficit conditions is very useful management practice for elimination negative effects of drought on maize yield. For example, in stationary field experiment on eutric cambisol of Agricultural Institute Osijek, maize yield in less favorable growing seasons (2000, 2007 and 2012) were increased compared to non-irrigated plot for 24.0%, 31.5% and 47.4%, respectively (*Table 4*).

Also, by correspondingly soil management, for example liming and fertilization, is possible to alleviate negative effects of drought and high temperature on field crops yield (Kovacevic and Basic, 1997; Sostaric and Josipovic, 2006; Antunovic, 2008; Markovic et al., 2008, 2013; Komljenovic et al., 2010, 2015; Andric et al., 2012; Stojic et al., 2012; Kovacevic and Loncaric, 2014; Kovacevic et al., 2015).

Table 4.

Impacts of irrigation on maize yields

Irrigation	Response of maize to irrigation (the experimental field of Agricultural Institute Osijek)										
	Grain yield of maize (t ha^{-1})**										
	2000	2002	2004	2006	2007	2008	2009	2010	2011	2012	Mean
Control (non-irrigated)	10.18	11.87	10.91	8.29	8.61	8.37	9.89	8.40	6.81	6.73	9.01
80–100% FWC*	12.62	12.44	11.97	10.32	11.32	9.65	12.20	8.56	9.23	9.92	10.82
$LSD_{5\%}$	0.65	0.13	0.49	0.27	0.44	0.30	0.22	ns	0.35	0.32	
Yield increase (%)	24.00	4.80	9.70	24.50	31.50	15.30	23.40	0	35.50	47.40	

Source: Josipovic (2013), Note: * maintenance of soil moisture by irrigation in range 80–100% field water capacity (FWC), ** 2000–2004: average of 3 fertilization + 4 replicates (12 individual results for each treatment), ** 2005–2012: average of 3 fertilization + 4 hybrids + 4 replicates (36 individual results for each treatment).

CONCLUSIONS

Maize, soybeans, sunflower and sugar beet are main field crops on arable land in Croatia. Weather conditions, particularly precipitation and temperature regimes, have considerable impact on yield of these four crops. With that regard, global warming and more frequency of the extremely weather conditions have often adverse influence on field crop yields as well the higher amplitude their variations among years. For example, in 15-year period (1999–2013) variation of annual yields were in ranges (t ha^{-1}) from 4.1 to 8.0 (maize), from 1.4 to 3.0 (soybeans), from 1.6 to 3.2 (sunflower and from 23.0 to 57.7 (sugar beet). In general, the lower precipitation in combination with the higher temperatures are associated with the lower yields of maize, soybeans and sugar beet, while sunflower yields were low in very moist years. The growing season 2014 was mainly very favorable for spring crops because of adequate and good distributed precipitation and moderate temperatures. Under these favorable weather conditions, annual yields of maize (8.1 t ha^{-1}), soybeans (2.8 t ha^{-1}) , sunflower (2.9 t ha^{-1}) and sugar beet 63.6 t ha^{-1}) were considerable higher than usual.

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